

Effects of Mature Shelterbelts on Microclimate and Crop Yield

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Abstract

A study was conducted at Conquest Saskatchewan, to assess the effects of mature Caragana (*Caragana arborescens* Lam.) shelterbelts on soil moisture, potential evaporation, windspeed, and crop yield. Snow trap near the shelterbelts increased spring soil moisture contents, in the immediate area near the shelterbelts, by as much as 25% above average field values. Potential evaporation and windspeed between the belts was reduced by as much as 23% and 36%, respectively. However, increased spring moisture, reduced evaporation and windspeed failed to produce significant yield differences as a function of distance from the shelterbelts. Severe moisture stress was the main factor limiting crop yield at the study site.

Introduction

Field shelterbelts have long been recognized as an effective means of protecting soils and crops from wind erosion. Modification of windspeed and flow is the primary effect of shelterbelts on microclimatic parameters, as exemplified by Marshall's (1967) review (Figure 1). While the actual numbers may differ, the curves approximate the direction and magnitude observed by many investigators. The horizontal axis is expressed in terms of barrier heights. Windspeed is reduced to the greatest extent within a few multiples of barrier height. The reduction diminishes with distance downwind to a height multiple of about 30H, where windspeed approaches that of open fields. Crop yield, soil moisture, and evaporation are influenced to a lesser extent than windspeed, while soil temperature (during the day), relative humidity, and air temperature (during the night) show relatively little variation as a function of distance from shelterbelts.

Staple and Lehane (1955) have shown that increased yield near prairie shelterbelts can be attributed to the effect of additional soil moisture resulting from accumulation of snow near the hedges. Pelton (1967) removed the influence of snow accumulation in order to isolate the effects of wind travel and potential evaporation on wheat yield during the growing season. He reported reductions in windspeed and potential evaporation of 15 to 49% and 23 to 29%, respectively. Although maximum grain yields were obtained in areas of maximum wind and evaporation reduction, Pelton reported that the yields were extremely variable within individual years and from year to year. Frank et al. (1977) found that yield of spring wheat increased significantly when grown under sheltered as compared to unsheltered conditions, provided adequate soil water was available to the crop.

The availability of soil moisture during the growing season appears to be the overriding factor governing the response of field crops to shelter. The shelter effect on yield can be expected to be most dramatic during years when plants near the center of the field experience moisture stress while those near the shelterbelts are unaffected by moisture stress because of the additional moisture available from trapped snow (years with high snow fall and low growing season precipitation). Conversely, the shelter effect can be expected to be least dramatic when crops experience severe moisture stress (years with low snow fall and low growing season precipitation) or when the crop experiences no moisture stress (years with high snow fall and high growing season precipitation).

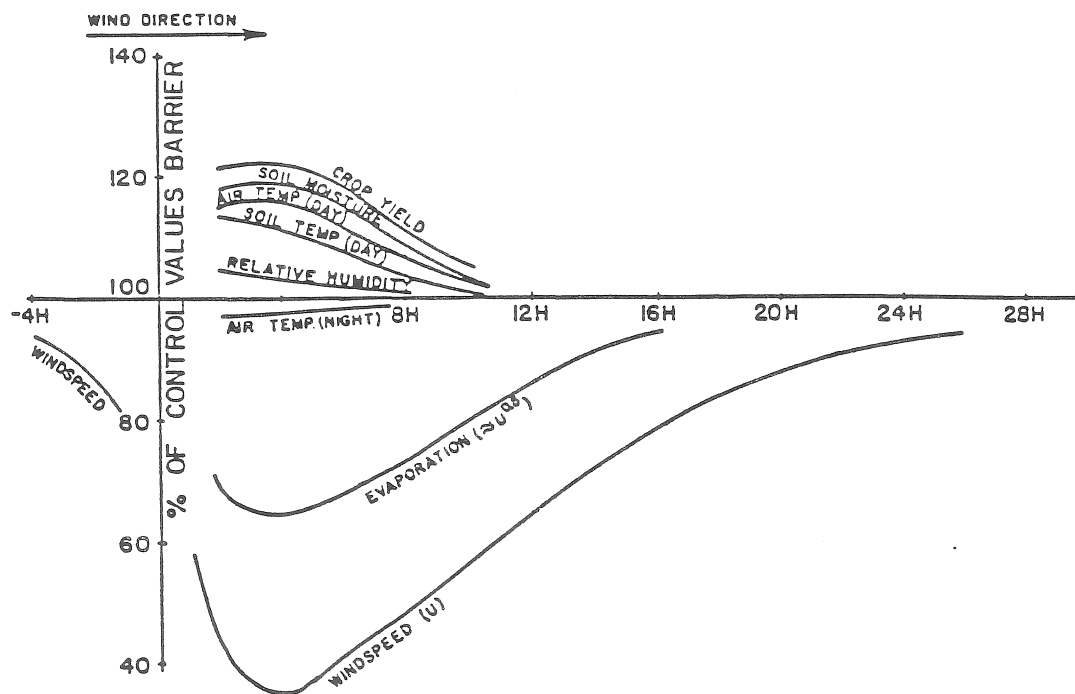


Figure 1: Summary diagram of the effect of barriers on micrometeorological and other indicated factors (Marshall, 1967).

Materials and Methods

Figure 2 summarizes the study that was conducted at the Conquest site. The soil at the site is an Orthic Dark Brown Chernozem (Bradwell very fine sandy loam) and has a slope percentage of less than 1%. The shelterbelts at the site are single row caraganas (6 m height) that were planted 0.3m apart and are oriented in a N-S direction. A transect was established perpendicular to the shelterbelts, extending across all three segments in an E-W direction. Spring soil moisture samples were taken at four different depths; 0-15 cm, 15-30 cm, 30-45 cm, and 45-60 cm. Durum was seeded in segment #1 (durum site) of the transect and 78 kg/ha of N in the form of ammonium nitrate was broadcast on an a strip adjacent to the original transect to control for variations in soil N fertility. Potential evaporation was monitored at a height of 1 m at various locations along the transect with spherical white Livingstone atmometers (Livingstone, 1935). Paired 3m² samples of both the fertilized and unfertilized transects were taken at various distances from the shelterbelts. A similar procedure was followed in segment #2 (wheat site). At segment #3 of the transect (fallow site) windspeed (1 m height) at various locations along the transect, and wind direction, were monitored in addition to measurements of potential evaporation. Windspeed was monitored with a cup anemometer (Model 014A, Met-One, Sunnyvale, CA., U.S.A.), and wind direction was monitored with a wind direction sensor (Model 024, Met-One, Sunnyvale, CA., U.S.A.). Data were recorded as 1-hour averages using a model CR-21X data logger (Campbell Scientific, Logan, UT, U.S.A.), stored on audio cassette and later transferred to a microcomputer for processing. A meteorological station

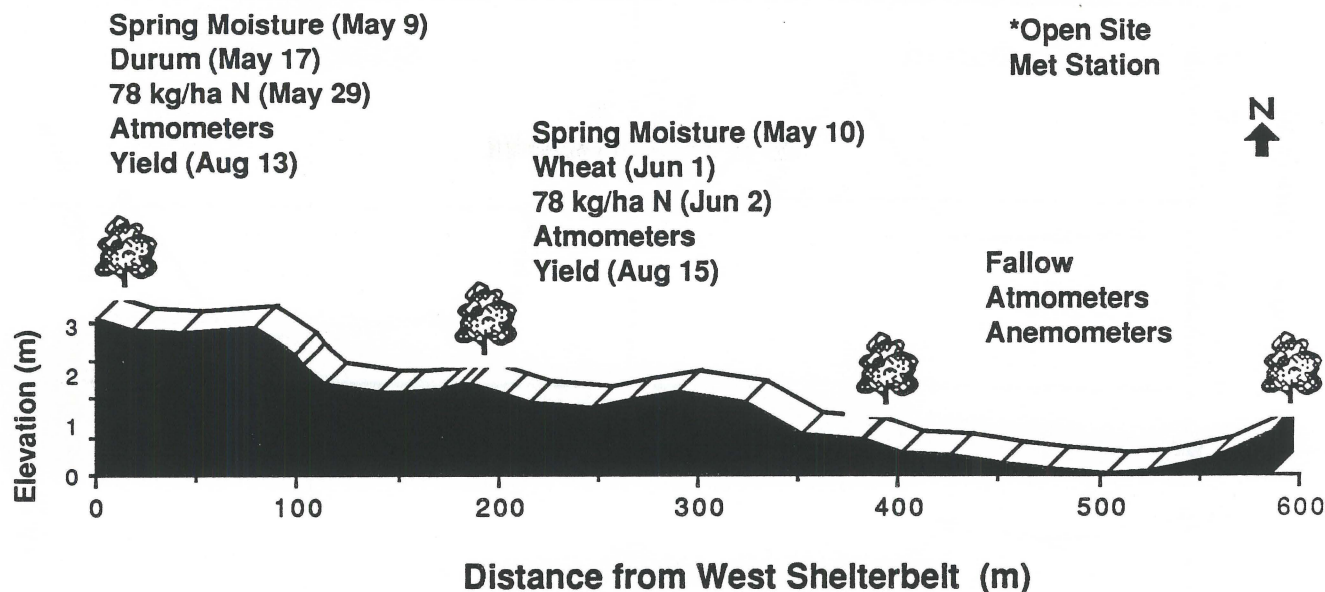


Figure 2: Graphical representation of the study site (note vertical exaggeration 33X).

with a data-logger, an anemometer, 2 atmometers, and a tipping bucket rain gauge was established in an open fallow field adjacent to the sheltered fallow site. The measurements from the meteorological station provided control values for the micrometeorological measurements within the sheltered site.

Results and Discussion

Spring moisture content (0-60 cm), in the immediate vicinity of the shelterbelts, was as much as 25% above the weighted mean spring moisture contents (Figure 3), which is likely a reflection of snow trapped by the shelterbelts. Soil moisture contents at greater distances from the belts reflect the influence of topography on soil moisture redistribution.

Potential evaporation at 6m (1H) from the east shelterbelt was decreased by as much as 23% below the values measured at the open fallow site and approached open site values towards the center of the field (Figure 4). Winds were predominantly from the north-west during the measurement period and wind velocities were reduced by approximately 36% at 6m (1H) from the west shelterbelt compared to windspeeds at 120m (20H); (Figure 5). Shelterbelts reduced evaporation proportionally less than windspeed and in similar proportions to those reported by Marshall (1967; Figure 1).

Average yields were relatively low at both the durum and spring wheat sites; 1500 kg/ha and 1400 kg/ha respectively (Figure 6). A paired t-test of the fertilized and non-fertilized treatments show that there was no significant difference due to fertilization ($\alpha = 5\%$) which suggests that moisture was limiting crop growth or that the farmer had adequately fertilized the two sites. Yields are known to be a function of the ratio between actual and potential evaporation. Based on the atmometer data we would expect yield near the shelterbelts

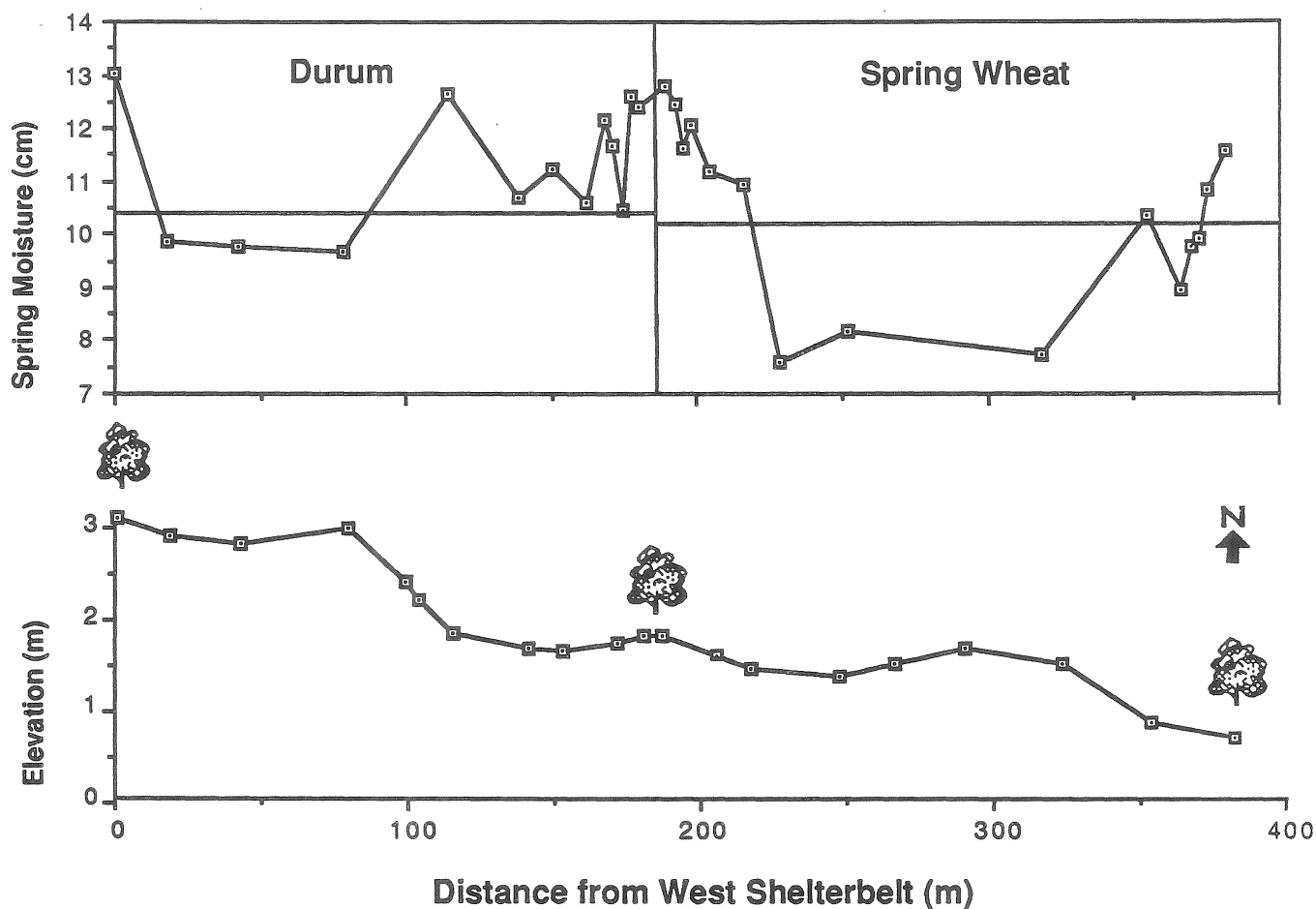


Figure 3: Spring moisture content and elevation as a function distance from the west shelterbelt.

to be significantly higher than yields at the center of the fields. However, the yield response as a function of distance from the shelterbelts was relatively flat for both sites (Figure 6). Competition by the belts for available moisture reduced crop yields by as much as 66%. Although the yield reduction zone was confined to a relatively small distance from the shelterbelts, when combined with the lost yield that results from the area occupied by the shelterbelts it represents a significant loss of potential yield on this field. A regression analysis of the spring moisture and yield data indicated that variation in grain yield could not be accounted for by variation in available moisture at seeding time. The lack of a shelterbelt effect with respect to yield regardless of decreases in potential evaporation and windspeed near the belts provides further evidence that moisture stress was the main factor controlling yields within the study area. Precipitation recorded at the site was 30% below the 30 year average for the area. Also, the distribution of the precipitation was skewed so that approximately 80% of the precipitation fell in May while only 20% fell in June and July.

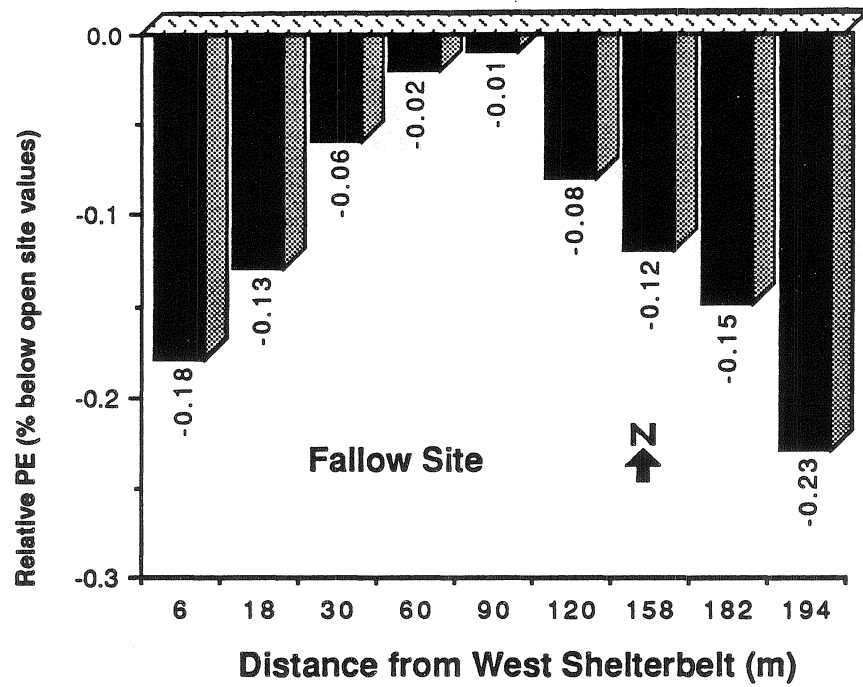


Figure 4: Potential evaporation as a function of distance from the west shelterbelt.

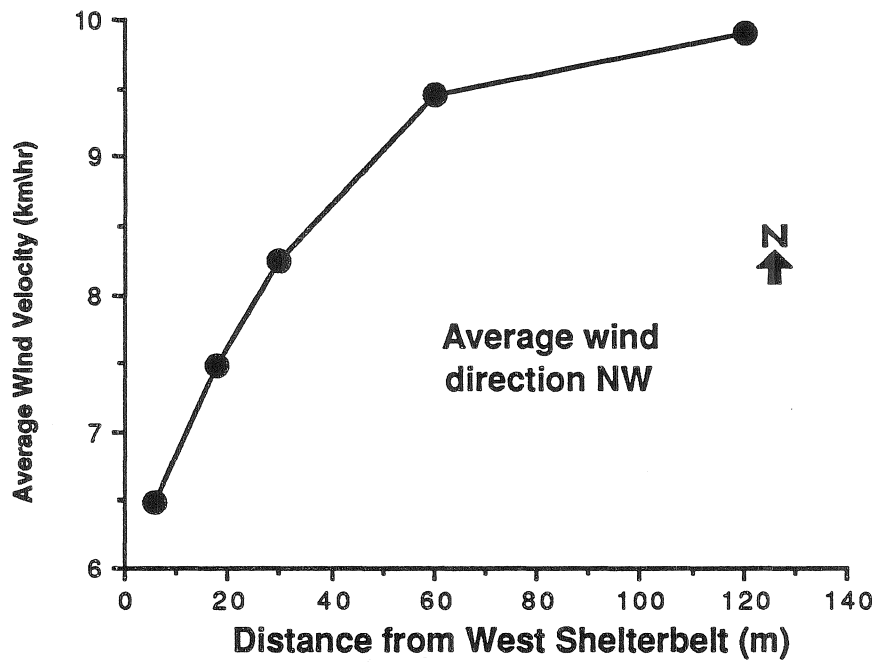


Figure 5: Average windspeed as a function of distance from the west shelterbelt.

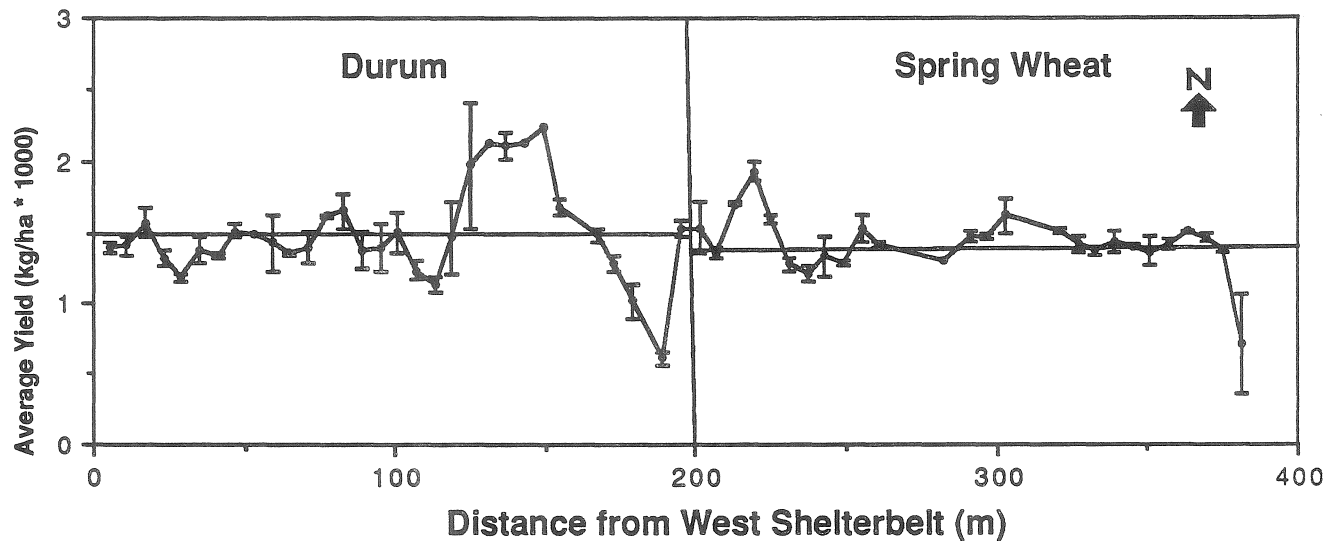


Figure 6: Durum and Spring wheat yields as a function of distance from west shelterbelts.

Conclusions

Shelterbelt-induced snow trap increased spring moisture near the shelterbelts by as much as 25% above the weighted mean soil moisture content for the study sites. The shelterbelts also reduced potential evaporation and windspeed by 23% and 36% respectively. However, increased yields did not occur next to the shelterbelts at this site because severe moisture stress limited crop growth.

References

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